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The young-of-the-year alewife Alosa pseudoharengus (Wilson) in Lake St. Clair with special reference to food habits and growth.

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THE YOUNG-OF-THE-YEAR ALEWIFE *ALOSA PSEUDOHARENGUS* (WILSON) IN LAKE ST. CLAIR WITH SPECIAL REFERENCE TO FOOD HABITS AND GROWTH

by

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ABSTRACT

Selected aspects of the life history and ecology of the alewife Alosa pseudoharengus (Wilson) in Lake St. Clair were studied at a location near Stoney Point, Ontario, from July 5 to October 29, 1971. Weekly sampling was carried out in an attempt to provide information on the time and location of spawning and subsequent food habits and growth of young-of-the-year of the species.

Successful spawning indicated by the continual appearance of young fish in the nets was estimated to occur in the first 3 weeks of June, beginning about June 1, when the water temperature reached 17°C.

The diet of the young alewives consisted primarily of copepod and cladoceran zooplankters. Copepods were found more frequently in the stomachs of the younger fish while cladocerans were more evident in the diet of larger individuals. The major organisms consumed were usually selected from the environment in order of decreasing size. The occasional major dietary importance of smaller copepods in the presence of larger cladocerans may be due to differences in patterns of locomotion. Rotifers were the major food items of young alewives only on occasions when the copepod-cladoceran group was reduced in the immediate environment of the schooling individuals. Limited feeding on benthic organisms in their natural habitat indicates that young-of-the-year alewives are facultative planktivores.

Growth rate of young fish showed two inflections. The first was related to the depletion of the copepod-cladoceran food resource and the second to decreases in temperature of the water column.

Relative growth data are presented as comparative material for future studies of young-of-the-year in freshwater.

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CHAPTER I

INTRODUCTION

Studies of food habits and growth of the freshwater alewife <u>Alosa pseudoharengus</u> (Wilson) in its first year of life are poorly represented in the literature.

Two analyses have shown the main source of nutrient for young-of-the-year fish to be zooplankton. Specific groups were differentially selected and consumed by young individuals (Norden 1968, Hutchinson 1971) in order of the largest organism available (Brooks 1968).

Growth determinations using the scale method and/or Huxley's Power Law for allometric growth (Pritchard 1929, Odell 1934, Graham 1956, Rothschild 1965, Brown 1972) have revealed little information on alewives less than one year of age. Growth data restricted to young-of-the-year are rare. Seasonal growth studies, and therefore correlations of food consumption and other variables with changes in growth rate on a temporal basis have not been attempted.

Despite the fact that the Great Lakes environment is favourable for the establishment of the early life stages of <u>Alosa</u> (Stanley and Colby 1971), publications concerning food habits and/or growth of young-of-the-year of this species have only been reported from the following lakes: Lake Ontario (Pritchard 1929, Graham 1956), Lake Erie (Price 1963) and Lake Michigan (Gross 1953, Brown 1972). Although the alewife has recently been reported as the most abundant species in Lakes Huron and Michigan (Stanley and Colby 1971), no information is available concerning its ecology in Lake St. Clair, a major link in the northward migration of this species (Miller 1957).

The adult alewife, although generally preferring colder, deeper waters, has been known to thrive in shallow lakes which do not exhibit standard thermoclines (Odell 1934). Even reproduction will occur providing that the lake has a central area free of vegetation (Gross 1953). A preliminary survey in 1969 indicated the probability of successful alewife spawning activity in or around Lake St. Clair (Lutzac 1969, unpublished).

In view of the preceding information, a field program was established to study young-of-the-year of the species with particular reference to:

1. Spawning activity and abundance.
2. Food habits and feeding selectivity patterns.
3. Determination of seasonal growth and changes in rate.
4. Determination of the major biological and physical factors associated with item 3.
5. Presentation of relative growth data as an aid to future studies.

This dissertation is the first report on the life history and ecology of the alewife in Lake St. Clair.

CHAPTER II

DESCRIPTION OF LAKE AND SAMPLING AREA

A. The lake

Lake St. Clair is situated on the Canada-United States border between Ontario and Michigan. It is connected to Lake Huron north-easterly by way of the St. Clair River, and to Lake Erie south-westerly via the Detroit River (Fig. 1.). It is the smallest and shallowest of the large lakes in the St. Lawrence Great Lakes chain (Beeton and Chandler 1966). Morphometric data are shown in Table 1.

The area is characterized by a temperature climate with an average annual air temperature of +8.9°C. July and January means are +21.7°C and +0.5°C respectively. Average annual rainfall is 76.2 cm and average annual snowfall 101.6 cm (Brown et al., 1968)[1].

B. The sampling area

The sampling area on the south shore of the lake in Tilbury Township, Essex County, Ontario, was located about 3.2 kilometers east of Stoney Point, adjacent to the Tremblay Creek Marsh (Figs. 1, 2, 3).

Upper Devonian shale and Columbus limestone forming the lake basin (Hough 1958) are covered by Brookston clay, a heavy soil with surface layers of fairly high organic content. This is overlaid in the shallower waters near shore, with a mixture of Berrien sand and Colwood fine sandy loam (Richards _et_. _al_. 1949). The bottom supports an abundance of

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1. See Phillips _et_. _al_. 1972 for more complete portrait on area climate.

hydrophytes which are dominated by *Myriophyllum* sp. *Potamogeton* spp., and *Scirpus* sp. in the sampling area.

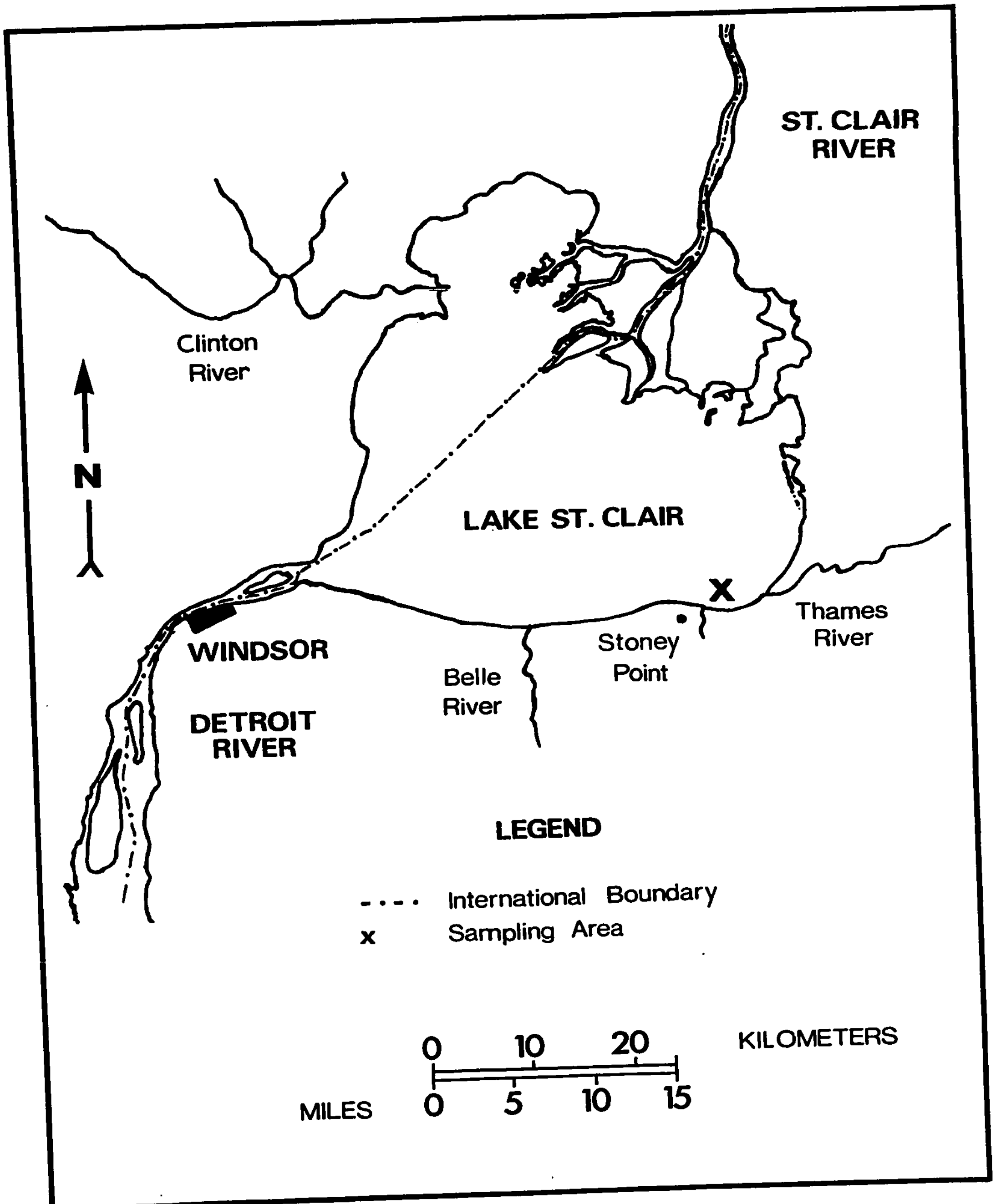


Fig. 1. Map of Lake St.Clair showing major drainage and sampling area.

Table 1. Morphometry of Lake St.Clair

Parameter	Measurement
Length	41.8 km
Breadth	38.6 km
Surface Area	1,269.0 km^2
Maximum depth	6.4 m
Mean depth	3.0 m
Mean elevation	175.2 m

After Beeton and Chandler, 1966.

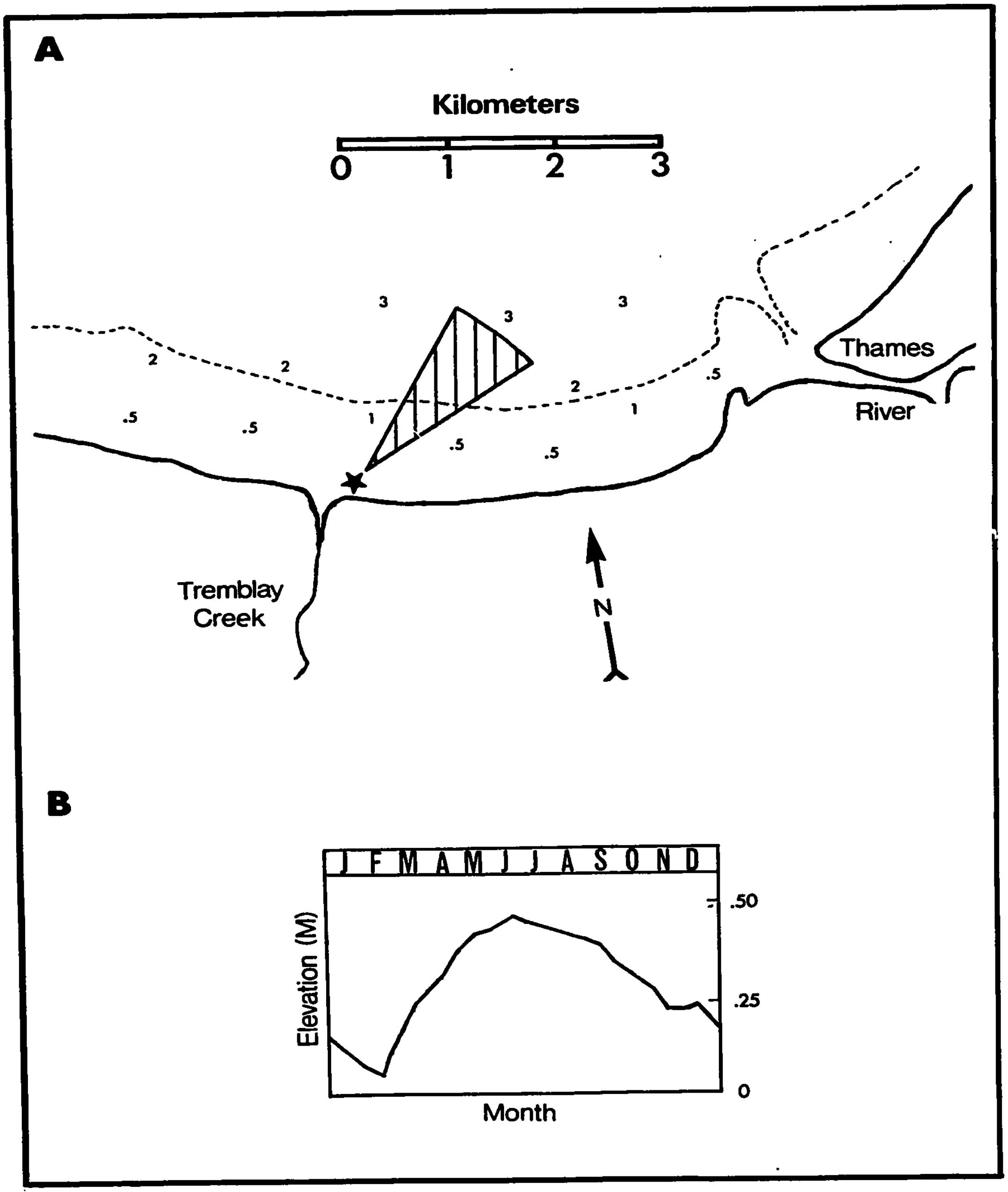


Fig. 2. A. Enlarged map of sampling area. ✶ = seining location. ◿ = trawling area (depth in metres). B. Lake St.Clair mean elevation (M), 1959-68. Plane of reference of this chart is low water datum 571.7 feet (U.S. Army Corps of Engineers (1969)).

Fig. 3. Inshore view of seining area.

CHAPTER III

MATERIALS AND METHODS

A. Field procedures

As soon as young-of-the-year alewife appeared, a weekly sampling program was begun. This lasted from July 5, 1971 to October 29, 1971.

An inshore and an offshore fish sample were taken on each field trip.

Inshore material taken at a maximum depth of 1.0 m (Fig. 2A,3) was collected using a 30 foot nylon bag-seine in 50 metre hauls, and a modification of the Haul Seine technique (Rounsefell and Everhart, 1953). Additional net dimensions are shown in Table 2.

In the 1953 procedure, the commercial seine, once set parallel to the shore in deep water, was landed from shore by a crew of men. Modification of this method for use in very shallow water with a smaller net eliminated the necessity of a boat, and required that only two men with chest waders be available for net handling purposes. Initially, the seine was towed by the lead man perpendicular to, and away from shore to a distance just beyond 50 metres. The second man then stopped, holding his line taut while the lead man circled to bring the net into position, parallel to shore. Both men then began a sustained shoreward net haul, each at the end of a short tow-rope.

Offshore samples (Bottom 1.5 - 3.0 m, Fig. 2A) were obtained using a modified 16 foot polyethylene otter trawl. The net was towed

Table 2. Seine net and otter trawl dimensions

Net type	Length	Additions	Depth	Width	Mesh size (Bar measure)			
					Wings	Bag	Body	Cod End
Seine	--	1.8 x 1.2 x 1.2 m*	1.8 m	9.1 m	4 mm	3 mm	-	-
Otter trawl	4.9 m	2.7 m**	0.9 m	5.0 m	19 mm	-	19 mm	6.3 mm

* Bag in middle of net

** Cod end attached to end of net body

behind a 17 foot by 6 foot English dory powered by a 70 horsepower Chrysler outboard engine at a minimum of 1.8 metres per second (commercial trawl speed). Additional net dimensions are shown in Table 2.

Trawl hardware and fishing procedures were similar to those described by Baldwin (1961) for use with outboard motor boats. Modifications of hardware and procedure included a separate warp, or haul line attached to each of 2 otter boards, rather than a single warp joined to them by a bridle, warp lines of 95 mm. diameter polyethylene rope, each 14 metres in length, instead of cable, and net landings executed manually at reduced engine speed as opposed to mechanically at trawl rpm.

With the boat describing a slow counter-clockwise circle, the trawl was deployed from back to front over the after port gunwhale. The doors, or otter boards, which spread the net laterally when deployed, were then unloaded simultaneously, one man per door, and the trawl warps laid out through the after eye-rings and secured on inboard cleats. After five minutes at trawl speed, engine rpm were reduced, and the trawl was loaded from front to back, again with the boat assuming a counter-clockwise path.

All fish samples to be analyzed in the laboratory were immediately preserved in 10% formalin (McAllister, 1965) and stores in Nasco Whirl-Pack bags.

During seining operations concerned with food habits and growth a weekly 10 litre plankton sample was taken from a depth of .25 metres in the vicinity of the seine haul, using a calibrated pitcher. Also during trawling operations, except for the last two weeks of the study, weekly 2 litre plankton samples were collected from depths of 2.0 and

3.0 metres in the region of the trawl zone, using a Van Dorn water bottle. As fish were available from shallower areas only (1 - 1.5 metres) on October 22 and 29, a weekly 2 litre plankton sample was collected in the area from a depth of 1.0 metre.

Plankton samples were concentrated to 100 cc. through a 28µ aperture Wisconsin net and stored in 3 per cent formalin.

Water column and surface temperatures were determined to the nearest 0.5°C using a Tri-R electronic thermometer and mercury bulb thermometer respectively.

B. Laboratory procedures

Young-of-the-year alewives were identified according to Norden, (1967b, 1968) and Mansueti and Hardy (1967).

For determination of seasonal growth rates, where possible, a random sample of 30 fish per net haul was measured. Ten fish per catch effort with lengths distributed proportionally over the range of the 30 fish and having approximately the same average value were used for stomach analysis.

Body measurements taken included length, measured in terms of standard length and total length to the nearest millimetre using a millimetre rule, and maximum depth and maximum width determined to the nearest 0.25 mm using a millimetre grid. Reference to length hereafter, unless otherwise stated, is to standard length.

Individual specimens were weighed to the nearest .01 gram on a Sartorius precision balance, model 2250.

Enumeration of gut contents was accomplished in a 1 ml.

Sedgwick-Rafter counting cell using a Wild dissecting scope and Reichert Visopan projection scope.

Plankton samples were counted using the Sedgwick-Rafter technique described by Welch (1948).

Organisms were identified according to Edmondson (1959).

C. Calculations

1. Food selection

Food selection was determined using the equation $E = \frac{r_1 - p_1}{r_1 + p_1}$ (Ivlev, 1961) where E = index of electivity, r_1 is the proportion of an organism or group of organisms in the total gut ration for a group of fish, and p_1 is the proportion of the same organism or group of organisms in the environment. Values of E may range between +1 and -1 to zero value indicating a lack of selection. Indicies between 0 and +1 indicate positive selection. Conversely indicies between 0 and -1 show negative selection.

2. Relative growth

Relative growth of a body part as compared to the entire body was determined using Huxley's Power Law for allometric growth:

$$y = bx^{\alpha}$$

where y is the weight, or size of the body part measured, x is body size, b is the initial growth index and α is the growth rate (Lewis and Taylor 1967). Empirical data for use with the equation were expressed in grams and millimetres.

3. Condition

Condition was calculated from the relationship $K = \frac{W \times 10^5}{\ell^{\alpha}}$ where K is the condition or plumpness factor, W is the weight in grams, ℓ is the standard length in millimetres (length from tip of snout to end of the vertebral column) and α is the value calculated in 2 above.

As the weight of organisms vary approximately with the cube of the length, values of 3 have been used by various authors as an approximation of α. Since this relationship is rarely exact for fish (Royce 1972) the α value calculated from length-weight data applied to Huxley's equation in 2 above was utilized in the calculation of K for the average length and weight of fish sampled on each date.

CHAPTER IV

RESULTS

A. Physical and chemical results

Physical and chemical observations are summarized in Table 3.

Temperature of the water column was uniform on individual sampling dates, ranging from a high of 25.5°C (July 8) to a low of 14.5°C (Oct. 9), with a mean of 22.7°C for the first 11 (July 5 - Sept. 10), and 16.7°C for the last 6 determinations (Sept. 18 - Oct. 29). A decrease of 4.3°C occurred in the Sept. 10 - 18 period. A possible significance of these temperature groupings will be discussed later.

B. Biological results

I. Spawning activity and abundance of young-of-the-year alewives

Despite the fact that attempts to collect eggs prior to July 5 and during the July 5 to October 29 interval were unsuccessful, young-of-the-year alewives were taken from Lake St. Clair during each of the 17 field trips from July 5 to October 29.

Length-frequency analysis of representative seine subsamples grouped by 5 mm length intervals showed that the smallest alewives (15 - 19 mm category) occurred in 9 of the 11 samples taken from early July to

Table 3. Water column temperatures in the area of fish operations

Date	Water column temp. (°C)
July 5	22.3
8	25.5
13	23.0
15	22.0
23	22.8
28	22.2
Aug. 6	21.1
14	22.3
22	23.8
31	22.0
Sept. 10	23.0
18	18.7
25	17.0
Oct. 2	17.8
9	14.5
22	16.1
29	16.0

early September. A unimodal size distribution was evident in samples collected during the period of July 5 - 15 and on July 28, a bimodal distribution was observed in samples July 23 and August 6 (Table 4).

The young fish appeared in 94% of the seine hauls and 86% of the otter trawls showing peak abundance on two occasions. Initial maxima were greater than the secondary peaks observed (Fig. 4).

2. Food habits and feeding selectivity

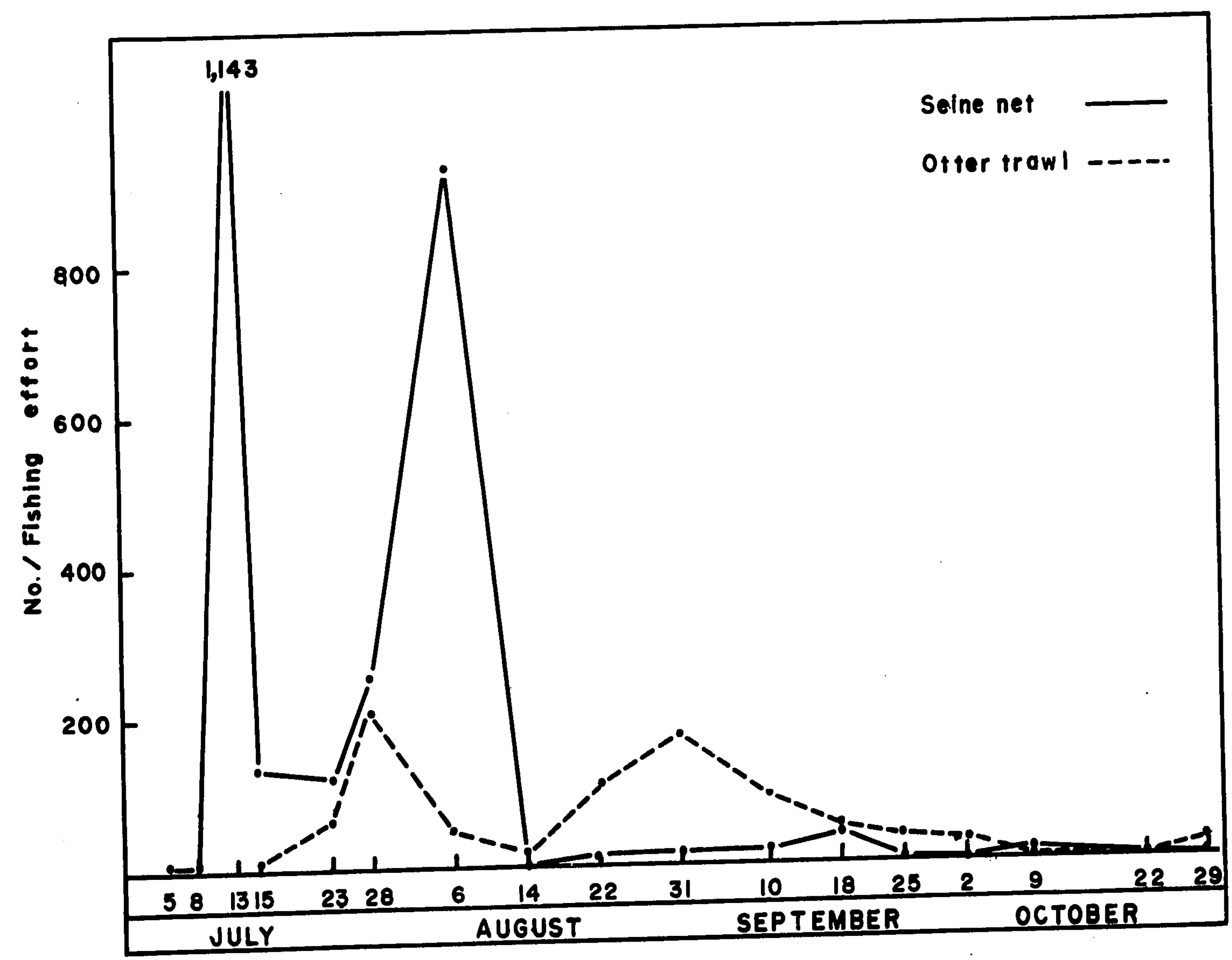
a. Zooplankton

Young-of-the-year alewives fed heavily on zooplankton. This food resource constituted 97.0% numerically of the total ration for 144 fish taken over a 4 month period. *Cladocera* (47.8%) and *Copepoda* (32.9%) were the two most important orders in the alewife diet. Both crustacean groups, of low density and forming small percentages of the zooplankton community on most occasions (Table 5) were always positively selected by feeding alewives (Fig. 5). Strength of selection in most cases was inversely related to the density of cladocerans or copepods in the environment. The *Rotifera* were only of intermediate value (16.5%) in the alewife food supply. They were the most abundant zooplankters (Table 5) but were never positively selected by the group of young fish examined (Fig. 5). Avoidance of rotifers was least when the combined cladoceran-copepod groups showed minimum counts of 17/ℓ on August 6. The *Ostracoda* (4.3%) contributed the least of the 4 crustacean orders to total stomach contents. Zooplankton eggs amounted to only 0.5% of total food consumed. Of the 6 cladoceran genera present in young-of-the-year gut contents, *Bosmina* (36.3%) was most abundant. *Daphnia* (2.5%), *Alonella* (1.5%), *Chydorus* (1.2%), *Leptodora* (0.2%) and

Table 4. Length-Frequency distribution of alewives from seine net sub-samples expressed as % composition of total number of fish examined. Modal length classes underlined July 5 - Aug. 6.

Standard Length (mm)		15-19	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-64	No. Examined
Date						Frequency (%)						
July	5	85.7	14.3									7
	8	44.4	55.6									8
	13	1.6	48.4	40.0	10.0							60
	15	16.8	20.0	46.8	13.4	3.4						30
	23	23.3	26.7	6.7	30.0	10.0	3.3					30
	28	4.0	78.0	14.0	4.0							50
Aug.	6		32.2	10.2	15.3	28.8	11.8	1.7				59
	14											0
	22	5.3	5.3	36.8	26.3		15.8	10.5				19
	31	5.3	21.1	10.5	10.5	5.3	21.0	21.0	5.3			19
Sept.	10	14.2	19.0	38.2	4.8			4.8		19.0		21
	18		7.2	4.9	2.1	2.1		12.0	66.8	4.9		42
	25		25.0	50.0	25.0							4
Oct.	2								100.0			1
	9				6.8	6.8			53.3	20.0	13.4	15
	22								100.0			2
	29					33.3			33.3		33.3	4

Fig. 4. Seasonal abundance of young-of-the-year alewives in seine and trawl net samples



No. / Fishing effort
200
400
600
800
1,143
Seine net
Otter trawl
5 8 13 15 23 28 6 14 22 31 10 18 25 2 9 22 29
JULY
AUGUST
SEPTEMBER
OCTOBER

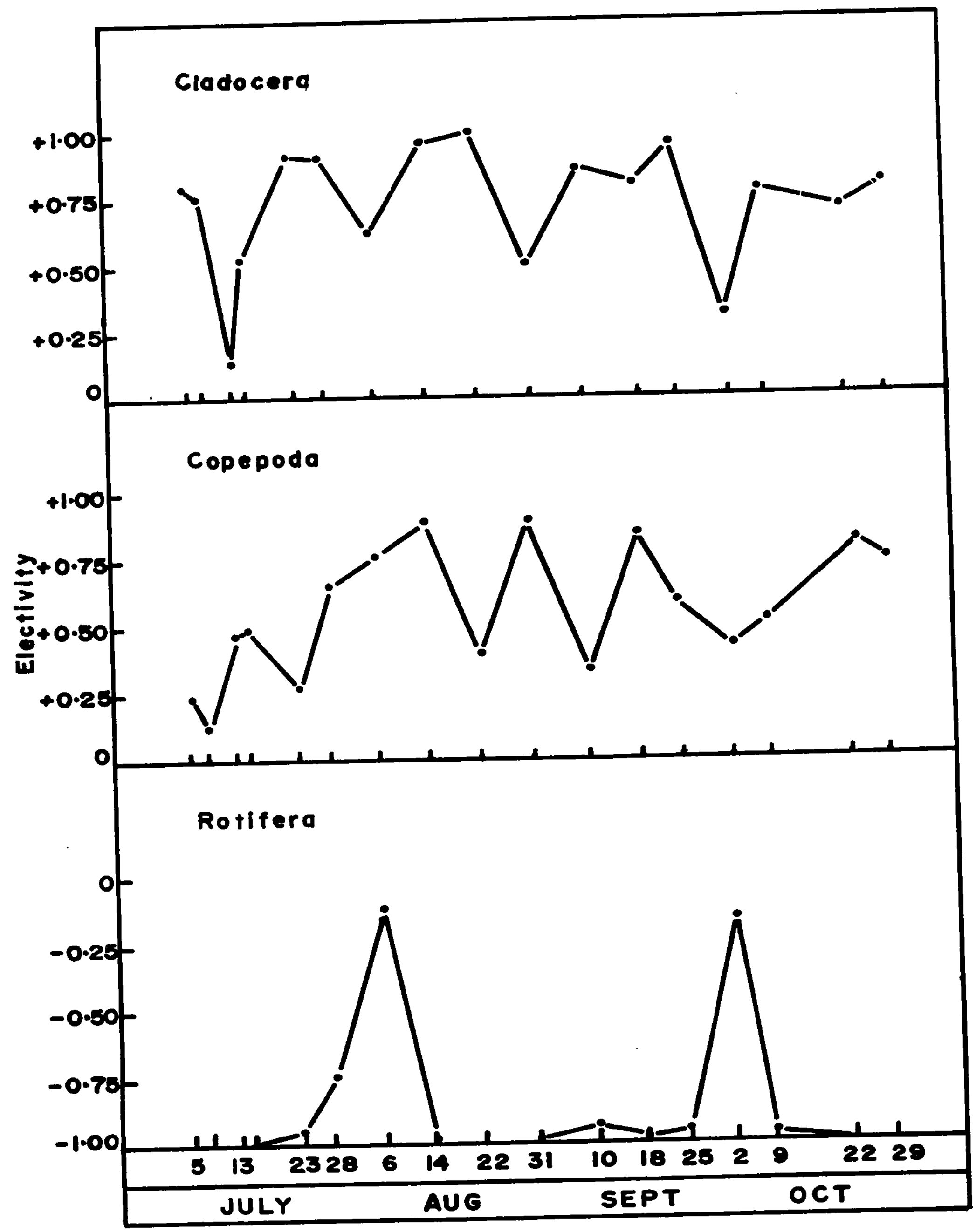
Table 5. Composition of the total number of metazoan zooplankters per litre in the area of fishing operations

	July 5		July 8		July 13		July 15		July 23		July 28	
	No./ℓ	%	No./ℓ	%	No./ℓ	%	No./ℓ	%	No./ℓ	%	No./ℓ	%
Cladocera	96.6	8.3	36.0	8.3	196.6	35.8	10.0	9.1	8.5	2.9	16.5	2.1
Alonella												
Bosmina	80.0	6.9	20.0	4.6	66.6	12.2	10.0	9.1				
Ceriodaphnia												
Chydorus			16.0	3.7								
Daphnia	16.6	1.4			130.0	23.6						
Copepoda	195.9	17.0	139.3	32.3	103.2	18.8	26.6	24.3	65.0	22.4	33.0	4.2
Rotifera	868.0	74.7	256.0	59.4	249.9	45.5	72.7	66.5	216.5	74.6	745.5	93.7

	Aug. 6		Aug 14		Aug. 22		Aug. 31		Sept.10		Sept.18	
	No./ℓ	%	No./ℓ	%	No./ℓ	%	No./ℓ	%	No./ℓ	%	No./ℓ	%
Cladocera	8.5	0.6	16.5	1.9	8.5	0.7	58.0	7.8	33.0	6.5	24.5	3.3
Alonella											8.3	1.1
Bosmina			16.5	1.9	8.5	0.7	58.0	7.8	16.5	3.2	16.5	2.2
Ceriodaphnia												
Chydorus									16.5	3.3		
Daphnia												
Copepoda	8.5	0.6	8.5	1.0	65.0	5.0	41.5	5.6	58.0	11.4	41.5	5.5
Rotifera	1,413.0	98.8	838.0	96.1	1,220.5	94.3	640.0	86.5	415.5	89.0	680.5	91.2

	Sept.25		Oct. 2		Oct. 9		Oct. 22		Oct. 29	
	No./ℓ	%	No./ℓ	%	No./ℓ	%	No./ℓ	%	No./ℓ	%
Cladocera	8.5	2.4	16.5	10.0	8.5	6.1	8.5	4.3	8.5	4.3
Alonella										
Bosmina							8.5	4.3		
Ceriodaphnia										
Chydorus										
Daphnia										
Copepoda	33.5	9.5	16.5	9.9	24.5	17.6	16.5	8.3	8.5	6.4
Rotifera	307.0	88.0	133.0	80.1	107.0	76.3	174.5	87.4	116.5	87.2

Fig. 5. Selection of 3 crustacean orders in the diet by young-of-the-year alewives


Cladocera
+1·00
+0·75
+0·50
+0·25
0
Copepoda
+1·00
+0·75
+0·50
+0·25
0
Electivity
Rotifera
0
-0·25
-0·50
-0·75
-1·00
5 13 23 28 6 14 22 31 10 18 25 2 9 22 29
JULY AUG SEPT OCT

Ceriodaphnia (0.1%) were of little overall value as food items. The copepods and rotifers found to be part of the alewife food supply but not enumerated at the genus level because of difficulties in identification (immature stages-copepods; extremely small sizes - rotifers) are listed with miscellaneous cladocerans in Table 6.

Cladocerans (21.9% - 70.5%) and copepods (14.2% - 72.8%) were present in the total ration of fish from all 5 mm size categories, while rotifers (0 - 42.3%) and ostracods (0. - 13.1%) were absent from stomach contents in at least half of them (Table 7, Fig. 6). *Bosmina* was responsible for the shape of the cladoceran percentage composition curve in all except the first 2 classes (15 - 19 mm, 20 - 24 mm) where cladocerans were not identifiable to genus. The shape of the copepod percentage composition curve was determined by the sum of copepodid and adult stages. Nauplii never contributed more than 2.7% of the total alewife stomach contents (Table 7).

On an individual sample basis, *Bosmina* totalled 97.0% of all cladocerans consumed by older alewives in the 11 samples taken after the beginning of August but only 47.2% of those cladocerans eaten by younger *Alosa* collected before the beginning of the same month. In this July 5 - 28 period, *Daphnia* (24.0%), *Alonella* (11.0%) and *Chydorus* (8.7%) were of increased importance in the alewife diet. *Daphnia* (July 8, 13), *Alonella* (July 23, 28) and *Chydorus* (July 28) made up more than 10% of the total cladocerans eaten, peaking in alewife stomachs on July 13, 23 and 28th respectively (Table 8A). The body length of excised cladocerans exclusive of spines and setae decreased in the following order: *Daphnia*, *Alonella*, *Chydorus*, *Bosmina* (Table 8B). All data were found to be

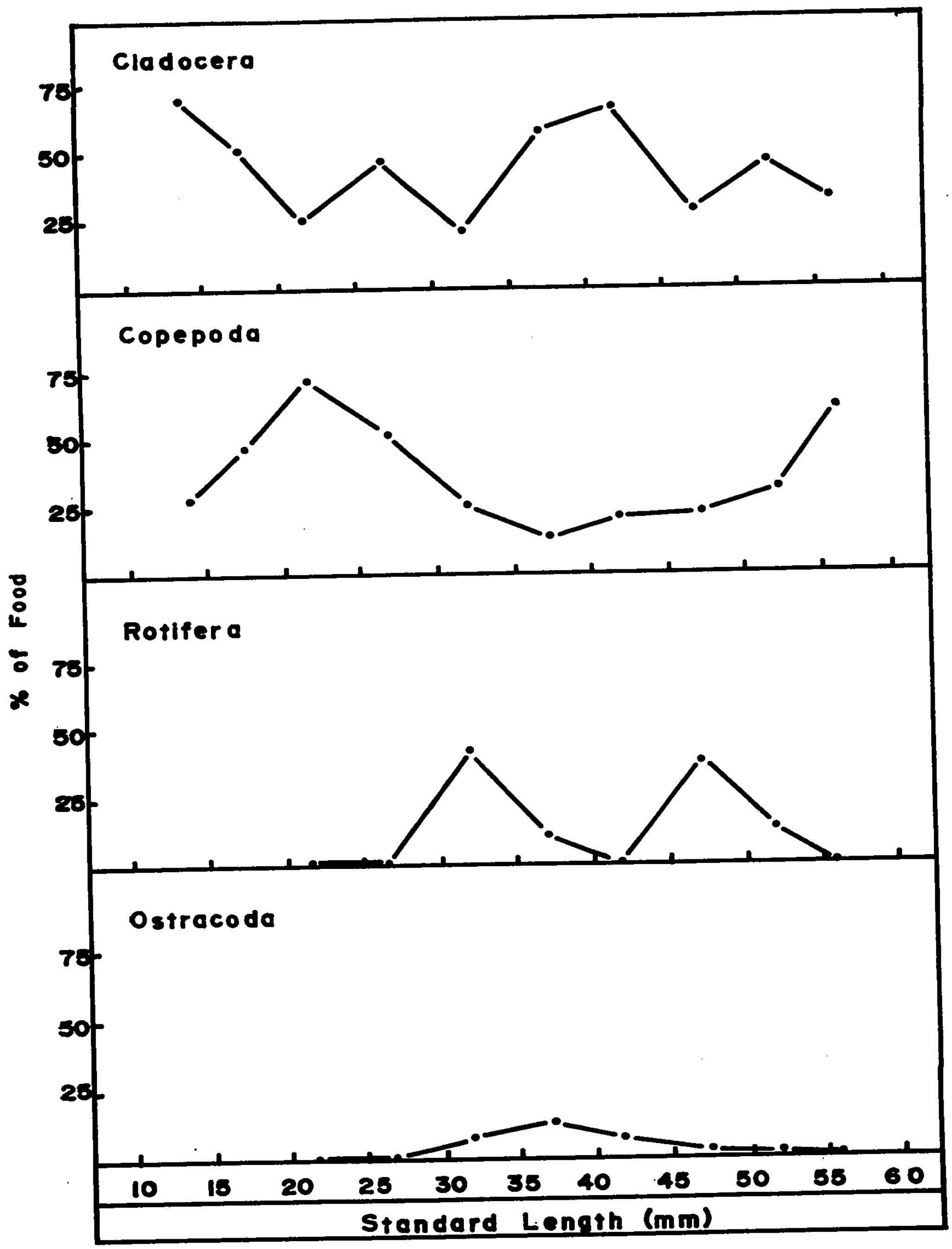
Table 6. Other crustaceans identified from stomach contents of young-of-the-year alewives.

Cladocera (occasional)	Copepoda		Rotifera
	Cyclopoida	Calanoida	
Ceriodaphnia	*Cyclops bicuspidatis*	*Epischura lacustris*	*Conochiloides*
Eurycercus lamellatus	*Cyclops vernalis*	*Eurytemora affinis*	*Keratella*
Sida crystallina			*Trichocerca*
			Ploesoma

Table 7. Food of young-of-the-year alewife grouped according to standard length, expressed as the number of organisms and percentage of the total food for each size class.

Size Class	10-14 mm		15-19 mm		20-24 mm		25-29 mm		30-34 mm		35-39 mm		40-44 mm		45-49 mm		50-54 mm		55-59 mm	
No. stomachs examined	2		11		14		13		15		13		20		20		28		8	
Food Item	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
ZOOPLANKTON																				
Cladocera	12	70.5	45	52.0	392	26.0	1,360	45.6	602	21.9	1,041	57.9	3,523	66.6	1,724	29.5	1,969	46.1	687	34.3
Alonella					6	0.4	44	1.5	89	3.2	157	8.8	22	0.4	21	0.4	36	0.8	33	1.6
Bosmina					219	14.4	812	27.4	277	10.0	712	39.6	3,389	64.1	1,690	29.0	1,912	44.7	642	32.0
Ceriodaphnia							10	0.3	7	0.4			4	-	4	-			5	-
Chydorus					1	-	56	1.9	22	0.8	150	8.3	79	1.5	3	-	3	-	7	0.2
Daphnia					71	4.7	415	14.0	175	6.3	4	0.2	3	-						
Leptodora					2	0.1	7	0.2	32	1.2										
Unknown	12	70.5	45	52.0	93	6.1	8	0.3			18	1.0	34	0.6	6	0.1	18	0.4		
Copepoda	5	29.5	41	48.0	1,109	72.8	1,558	52.3	740	26.9	256	14.2	1,079	20.4	1,351	23.0	1,381	32.2	1,210	60.0
Adult and copepodids	5	29.5	41	48.0	1,109	72.8	1,557	52.3	729	26.5	247	13.7	1,078	20.4	1,287	21.9	1,266	29.5	1,177	58.4
Nauplii							1	-	11	0.4	9	0.5	1	-	64	1.1	115	2.7	33	1.6
Ostracoda					4	0.3	9	0.3	215	7.8	235	13.1	410	7.8	184	3.2	72	1.7	18	0.9
Rotifera					12	0.8	3	0.1	1,164	42.3	217	12.1	17	0.3	2,320	39.7	631	14.7	17	0.8
Eggs													11	0.2	108	1.9	3	-		
OTHERS																				
Chironomidae					1	-	13	0.4	19	0.7	48	2.7	209	4.0	133	2.3	191	4.5	44	2.2
Larvae					1	-	13	0.4	19	0.7	48	2.7	209	4.0	117	2.0	191	4.5	44	2.2
Pupae															16	0.3				
Unknown					7	0.1	25	0.8	1	-			33	0.6	18	0.3	28	0.7	23	1.4
Sand grains					1	-			1	-	4	-	144	-	119	-	1,969	-	687	-

Fig. 6. Contributions of 4 crustacean orders to total zooplankton in stomachs of 10 length groups of young-of-the-year alewives (Empirical data are for average length of fish in each 5 mm category).



Cladocera
Copepoda
Rotifera
Ostracoda
% of Food
75
50
25
10
15
20
25
30
35
40
45
50
55
60
Standard Length (mm)

Table 8A. Contributions of 5 genera to total cladocerans consumed by young-of-the-year alewives from selected samples (July 5-28, 1971).

Date	Total Cladocera	Alonella No.	Alonella %	Bosmina No.	Bosmina %	Chydorus No.	Chydorus %	Daphnia No.	Daphnia %	Leptodora No.	Leptodora %
July 5	29										
8	115							18	15.6		
13	1,378			741	53.7	4	0.3	598	43.4	8	0.6
15	647			486	75.1	62	9.6	33	5.1	45	7.0
23	260	189	72.7	46	17.6	1	0.4	14	5.4		
28	339	115	33.9	33	9.7	174	51.3				
Total	2,768	304	11.0	1,306	47.2	241	8.7	663	24.0	53	1.9

Table 8B. Lengths of 4 cladoceran genera removed from stomachs of selected samples of young-of-the-year alewives (July 5-28, 1971).

	No. measured	Length range (mm)	Average length (mm)	P
Daphnia	23	0.32-1.40	0.89	<.05
Alonella	8	0.41-0.78	0.66	<.05
Chydorus	5	0.48-0.55	0.50	<.05
Bosmina	21	0.25-0.60	0.37	

significant at the .05 level with the Student's t-test.

In this same period copepods constituted 51.8% of the alewife diet. Daphnia was the only cladoceran in fish stomachs found to be larger than this crustacean order ($P < .05$).

Rotifers constituted a major part of the Alosa diet only in the 30 - 35 and 45 - 50 mm length categories (Fig. 5). Smaller fish examined from July 28, August 6 and October 2 samples had consumed significantly more rotifers than did larger fish from the corresponding samples (Table 9).

In these same 3 samples, other food organisms deviated from a 1:1 ratio in stomachs of the 2 groups. Bosmina was more numerous in guts of the smaller alewives (Aug. 6, Oct. 2), while Alonella (Oct. 2), Chydorus (July 28) and Chironomidae and Ostracoda (Aug. 6) were more abundant in stomachs of the larger fish. Copepods were more evident in guts of both groups (smaller fish Aug. 6, larger fish Oct. 2). The data for the association between fish and food sizes were significant in 7 of the 11 comparisons made. This relationship was not apparent for the other 4 comparisons due to the occurrence of single overlapping values in the range of the means.

B. Other organisms

The other 3% of the alewife diet consisted of chironomid larvae and pupae (2.4%) and unidentified forms. Chironomids were more important to the larger fish showing small percentage composition peaks in stomachs of the 40 - 44 mm (4.0%) and 50 - 54 mm (4.5%) length categories (Table 7) and attaining densities greater than 10 per gut later in the study (Aug.

Table 9. Differential abundance of 7 food items in stomachs of smaller and larger young-of-the-year alewives in selected samples.

Date	No. Fish	Length range (mm)	Average length (mm)	Food Item																				
				Rotifera			Bosmina			Copepoda			Alonella			Chydorus			Ostracoda			Chironomidae		
				No./S*	Range	P	No./S*	Range	P	No./S*	Range	P	No./S*	Range	P	No./S*	Range	P	No./S*	Range	P	No./S*	Range	P
July 28	5	20-34	30.0	20.6	9-40	<.05										3.8	1-11	-						
	5	35-41	37.8	2.4	0-7											31.8	0-89							
Aug. 6	5	30-37	33.2	238.4	44-658	<.05	5.6	1-11	<.05	10.2	0-15	-							5.6	4-9	<.05	0.4	0-1	<.05
	5	38-45	40.4	15.8	2-68		1.2	0-4		3.6	1-7								17.0	2-24		3.8	1-8	
Oct. 2	5	46-51	48.8	547.2	122-884	<.05	115.6	72-200	-	25.6	16-39	<.05	0	-	<.05									
	5	52-57	54.8	30.8	0-139		63.8	36.96		221.6	25-341		5.8	0-9										

*No./S = Mean number of organisms per stomach.

22, Oct. 2, 9, 29, Table 10). They showed the same trends in gut analyses as sand grain counts (Table 7, Table 10).

3. Growth

a. Seasonal growth

Average length of young-of-the-year alewife increased from 17 mm on July 5 to 53 mm on September 25 and remained almost constant through October. Extremes determined by the standard deviation of the mean also increased continuously for the first 13 data points (Table 11).

Although a linear increase in length with time was not observed over the entire season, inspection of the data showed two regions of inflection (July 13-23 and September 10 - October 2) which permitted the estimation of seasonal growth in linear terms. The straight lines best describing the data (Table 12) were plotted along with the empirical values in Figure 7A and merged at the 2 points of inflection.

Growth rate during the study period was found to be maximal from July 5 - 13 (1 mm/day) intermediate from mid-July through all of August and early September (0.42 mm/day), and minimal through the last half of September and all of October (0.02 mm/day).

b. Seasonal growth and total food consumption

The temporal feeding pattern of young-of-the-year alewives appeared to be cyclic (Figure 7B). The only indications of a larger stomach capacity with increase in fish size were the successive increments in stomach contents for the three observed maxima (July 13, Aug. 22, Oct. 2). Minima in the number of organisms stomach were evident on 2 occasions (July 23, Sept. 18).

Table 10. Seasonal abundance of chironomids and sand grains in stomachs of young-of-the-year alewives

Date	No. Chironomids/stomach	No. Sand grains/stomach
July 5	0	0.1
8	0	0
13	0	0
15	0.6	0
23	1.6	0
28	5.3	0.1
Aug. 6	2.0	0
14	3.0	0.4
22	18.6	34.6
31	7.9	6.0
Sept. 10	4.4	5.9
18	7.5	3.7
25	2.6	4.0
Oct. 2	2.2	459.6
9	11.0	107.5
22	1.3	1.0
29	15.0	46.8

Table 11. Standard length measurements of young-of-the-year in 17 successive alewife samples

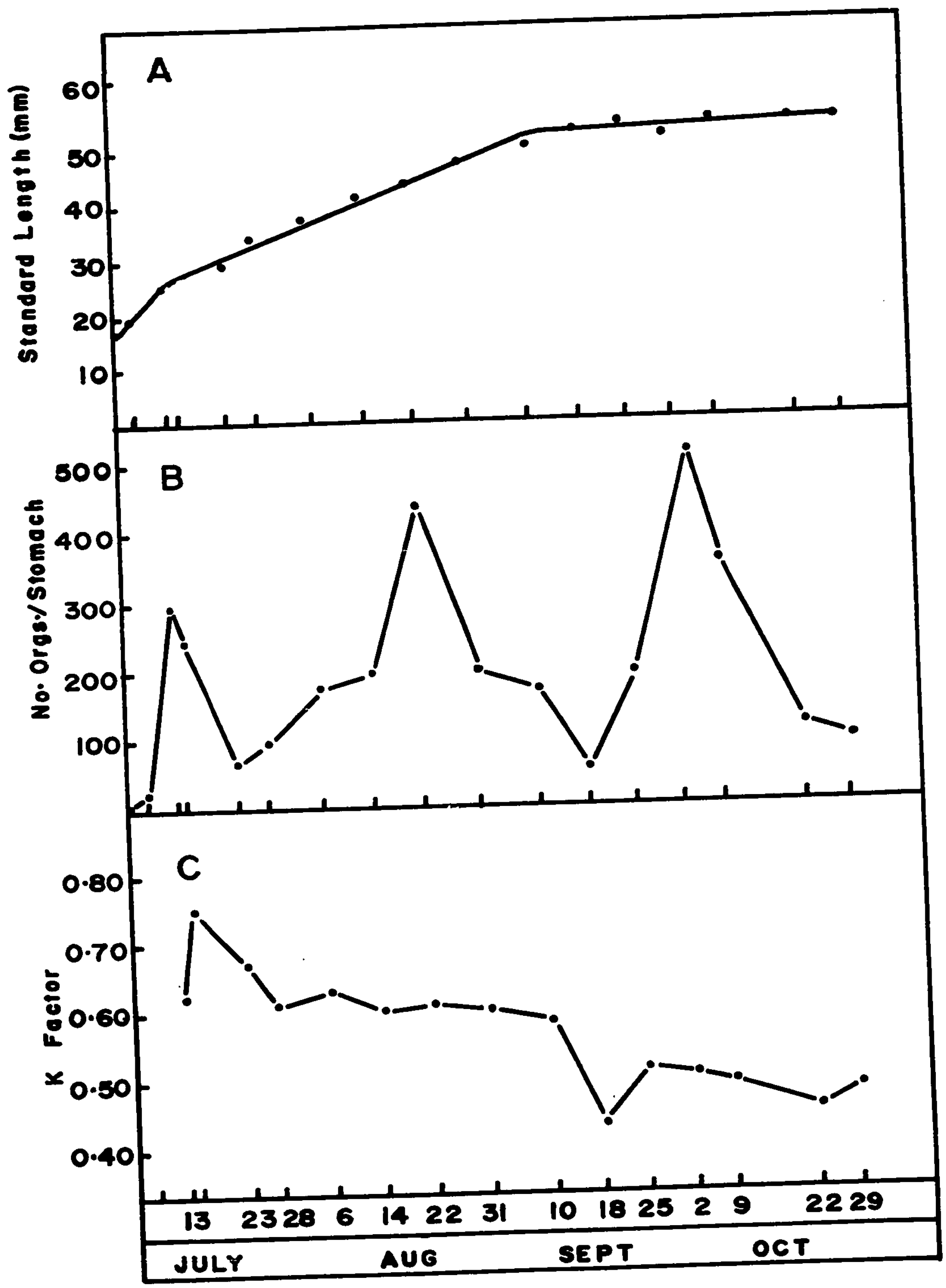
Date	Examined (No.)	Standard length (mm)	σ (mm)	Standard length Range (mm)
July 5	7	17	± 2.0	15 - 21
8	8	20	± 0.53	19 - 20
13	30	25	± 2.8	21 - 32
15	30	26	± 3.3	19 - 34
23	30	29	± 3.4	23 - 36
28	30	34	± 4.0	24 - 43
Aug. 6	30	37	± 4.3	30 - 47
14	21	41	± 2.4	36 - 46
22	30	43	± 2.5	39 - 50
31	30	47	± 3.0	40 -53
Sept. 10	30	50	± 2.5	45 - 54
18	25	52	± 2.8	46 - 57
25	30	53	± 3.1	47 - 59
Oct. 2	31	52	± 4.1	46 - 61
9	15	53	± 4.0	48 - 63
22	3	53	± 0.58	52 - 53
29	25	53	± 1.6	50 - 57

Table 12. Seasonal growth rates of young-of-the-year alewife described by linear equations. (y = standard length in mm, x = time in days, n = number of data points).

Date	Equation	n	p
July 5 - 13	$y = 1.000\ x + 16.0$	3	<.01
July 15 - Sept. 10	$y = 0.423\ x + 22.3$	8	<.01
Sept.18 - Oct. 29	$y = 0.020\ x + 50.7$	6	<.05

Fig. 7. Seasonal variation in young-of-the-year alewife (A) growth rate, (B) food consumption and (C) condition. (Size of fish measured as standard length in mm, food consumption as the number of food organisms/fish stomach, and condition as the K factor).

33


A
Standard Length (mm)
60
50
40
30
20
10
B
No. Orgs./Stomach
500
400
300
200
100
C
K Factor
0·80
0·70
0·60
0·50
0·40
13
23
28
6
14
22
31
10
18
25
2
9
22
29
JULY
AUG
SEPT
OCT

With young Alosa grouped by 5 mm intervals feeding activity showed 2 maxima (25 - 29 mm, 45 - 49 mm) and 2 minima (35 - 39 mm, 50 - 54 mm); the second of each being greater than the first. Sixty-nine per cent of fish in the 25 - 29 maximum food category came from samples taken July 15 or earlier when growth rate was at or near the maximum, while 100% of young alewives in the 35 - 39 mm minimum food grouping were taken July 23 or later when growth rate was intermediate. Sixty-five per cent of Alosa in the 45 - 49 mm maximum food division were taken earlier than Sept. 18 while 35% of those in the 50 - 54 mm minimum food range were collected on September 18 or later, when the growth rate was minimal.

c. Condition

Condition of young-of-the-year Alosa according to the equation $K = \frac{W \times 10^5}{\ell^{3.22}}$ showed some variation with time. The K value reached a maximum early in the growing season (July 15) just after the observed maxima in the number of organisms stomach of July 13 and showing a general decreasing trend thereafter to minimum values in the fall (Fig. 7c). The greatest changes occurred in the July 13 - 15 (increase) and Sept. 10 - 25 periods (increase and decrease).

d. Relative growth

Equations representing the relative growth of 4 body parameters against standard length for 134 young-of-the-year alewives grouped by mm intervals (Appendix 1) are shown in Table 13.

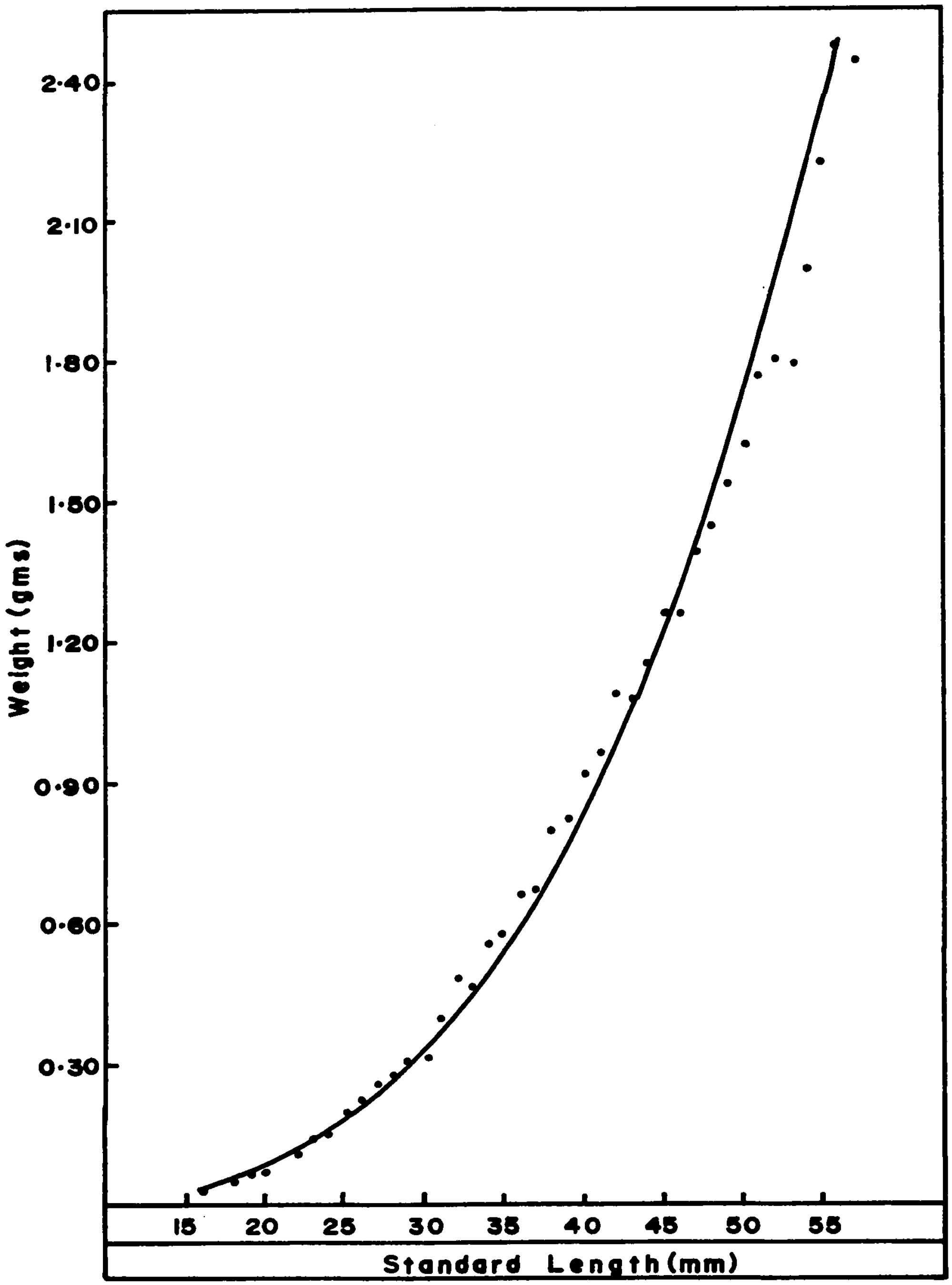
Growth in terms of body weight ($\alpha = 3.22$) caudal fin length ($\alpha = 1.12$), body width ($\alpha = 1.23$) and depth ($\alpha = 1.42$) was all relatively more rapid than that in terms of standard body length (Tachyauxesis).

Table 13. Relative growth of 4 body parameters against standard length for young-of-the-year alewives (y = size of body part (mm), x = standard length (mm)).

Comparison	Equation	P
Caudal fin length - standard length	$y = 0.15\,x^{1.12}$	<.01
Maximum body width - standard length	$y = 0.050\,x^{1.23}$	<.01
Maximum body depth - standard length	$y = 0.055\,x^{1.42}$	<.01
Weight - standard length	$y = 0.00000582\,x^{3.22}$	<.01

Empirical data and the calculated power curve expressing the length-weight relationship are plotted in Figure 8. The equation in linear form is $\log w = 3.22 \log L - 5.24$. All data were significant at the .01 level.

Fig. 8. The length-weight relationship for 134 young-of-the-year alewives.


Weight (gms)
2·40
2·10
1·80
1·50
1·20
0·90
0·60
0·30
15
20
25
30
35
40
45
50
55
Standard Length (mm)

CHAPTER V

DISCUSSION

A. Spawning activity and abundance of young-of-the-year alewives

As the young are known to remain in the spawning area until the late larval stage (Threinen, 1958) our failure to collect alewife eggs in shallow lake waters (Odell 1934, Norden 1967a) on sand and gravel bottom (Threinen, 1958) where this river herring normally spawns, may have been due to the occurrence of this activity in erratic areas (Miller 1930). Eggs were not found in a local barrier-beach type pond (Bigelow and Welsh 1925) nor were they evident from waters of the lake proper up to 10 feet in depth (Edsall 1964). Because the alewife may spawn in very narrow streams (Mansueti 1956) only 0.5°C warmer than surrounding waters (Collins 1952), it is possible that this event occurred in nearby Tremblay Creek (Fig. 2) or the adjacent marsh area.

The observation of two peaks in seine catches (Fig. 4), and bimodal fish size distribution of July 28 and August 6 following a series of successively larger unimodal peaks (July 5 - 15) are evidence for the occurrence of 2 major spawning periods. More larvae were produced from the first than from the second (Table 4).

Norden (1967a) found that developing eggs and larvae of Alosa were present in Lake Michigan during a four week spawning period in July when the water temperature had reached 17.5°C. Similar results were obtained by Pritchard (1929) in Lake Ontario.

If the larvae attain a length of 15 mm one month after hatching

(Bigelow and Schroeder, 1953) the smallest young-of-the-year taken from Lake St. Clair on July 5 (17 mm total length, 15 mm standard length) hatched on or about June 5 while the same size fish collected on July 23 emerged from the egg capsule on or about June 23. If 6 days' incubation at 15.6°C is necessary for hatching (Hildebrand 1963) new Lake St. Clair larvae of June 5 were spawned around June 1. As the surface waters in our sampling area reached 17°C on this date the water temperature data support the beginning of spawning activity in Lake St. Clair at this time.

B. Food habits and feeding selectivity patterns

The data for young-of-the-year alewives from Lake St. Clair showed that fresh water *Alosa* are primarily planktivores, selectively feeding on cladoceran and copepod zooplankters. This has been reported for various sizes of young *Alosa* in other lakes. For Lake Michigan individuals 60 - 119 mm in total length, 89.0% of the stomachs examined contained copepods while only 50.0% held cladocerans (Morsell 1968). For Lake Erie *Alosa* 25.4 - 76.2 mm in total length, cladocerans (89.7 - 92.1%) and copepods (40.0 - 79.7%) also occurred in a much greater percentage of stomachs than any other food item (Price 1963). For Lake Michigan alewives 5.9 - 39.7 mm in total length Norden (1968) showed that cladocerans and copepods constituted more than 75% of the diet by number and with one exception for the copepods, were positively selected. Hutchinson (1971) from Black Pond studies reported that the cladoceran genus *Bosmina* was positively selected by young alewives. Brooks (1968) has shown in the laboratory that schools of young *Alosa* in the presence of a limited food supply feed on progressively smaller (shorter) organisms as each resource approached depletion.

The progressive decrease in the size of cladoceran species found in stomach contents of young <u>Alosa</u> from Lake St. Clair during the July 5 - 28 period (Tables 8A,B) until this segment of the diet was dominated by <u>Bosmina</u>, suggests that selection of the largest zooplankters available occurs in the natural habitat. The stomach analyses and zooplankton data from July 8 collections supports this conclusion. A larger (length) cladoceran species <u>Daphnia retrocurva</u> was present in alewife stomach contents even though it occurred in densities too low to detect in the volume of water collected, whereas a smaller species <u>Chydorus sphaericus</u> appeared in the zooplankton but not fish stomachs. Hutchinson (1971) proposed that alewives preferred a diet of shorter cladocerans to longer cyclopoids because of the greater visibility of the cladocerans due to their greater body width in comparison with that of the copepods. In the present study copepods in stomachs of young alewives were longer than most cladocerans and narrower than all of them. In the July 13 samples, copepods were less abundant than <u>Daphnia</u> in the zooplankton samples but constituted twice as many (41.0% by number) of the total stomach contents. It is evident that other factors such as patterns of locomotion may be of some importance in addition to body length and width in the determination of their value as a preferred food item as observed in the July 13 sample.

The occurrence of rotifers as occasional major food items despite general avoidance of this potential resource by Lake St. Clair alewives (Fig. 5,6), has previously been reported for young Lake Michigan

Alosa 15.8 - 24.9 mm in total length (Norden 1968). He was unable to explain this occurrence as gill rakers of the young fish developed into efficient zooplankton sieves only after the young river herring reached a total length of 35 mm. In the present study the occurrence of wide variations in the percentage composition of rotifers in the stomachs of fish with fully developed gill rakers indicates that active selection also occurs for these smaller food items.

Brooks (1968) indicated that rotifers were consumed only by the earliest larval stages of the species. Hutchinson (1971) has shown that rotifers were never an important component of the diet of young alewives 34.0 - 73.0 mm in total length. The abundance of rotifers in the stomachs of Lake St. Clair alewives up to four months old in the July 28, August 6 and October 2 samples is probably due to the decrease in the natural population of copepods and cladocerans observed at these times (Fig. 9 B,C, Table 7).

The unusual distribution of food items in the stomachs of young fish in these samples (Table 9) reflects this scarcity of food and suggests some information on the structure of the fish school. The larger food items removed from stomachs of the large fish are characteristically associated with the water column (Alonella, Chydorus) and benthos (Ostracoda, Chironomidae). The smaller organisms removed from the stomachs of small Alosa are associated only with the water column (Bosmina, Rotifera). Since alewives have been shown to eat the larger items available, this distribution of food items in fish stomachs would be expected in the presence of a reduced food supply if the larger fish swim at the perimeter or anterior of the school and smaller individuals occur within or lag behind.

The presence of chironomids in the stomachs of young alewives reflects the existing confusion in the literature over the exact nature of their feeding habits. Odell (1934) and Hutchinson (1971) showed no evidence for benthic feeding by alewives. Brooks (1968) claimed that freshwater Alosa are obligate planktivores. Morsell and Norden (1968) have reported the presence of normally benthic chironomids in alewife stomachs but not in association with bottom feeding since both mature and immature chironomid larvae exhibit vertical migration (Hamilton, 1965). In the present study as the number of chironomid larvae and sand grains in fish stomachs varied directly with each other (except for September 18 and October 2 samples) the young alewife appears to be a facultative, rather than obligate, planktivore. On September 18 (Table 10) young alewives fed more heavily on chironomid pupae, which in addition to larvae, are known to migrate away from the benthic environment (Reid 1967). The occurrence of more chironomids and less sand in stomachs of young alewives in this instance appears to be the result of temporary relocation of the benthic resource in the water column. On October 2 chironomid pupae were not found in alewife stomachs and the number of larvae evident were at minimum levels. The presence of few chironomid larvae and large amounts of same in stomachs of young alewives here appears to be the result of intensified feeding on reduced numbers of this food resource.

Morsell and Norden (1968) reported that normally benthic organisms were found in the stomachs of some fish but indicated no positive relationship between benthic organisms and sediment in stomachs of the fish examined.

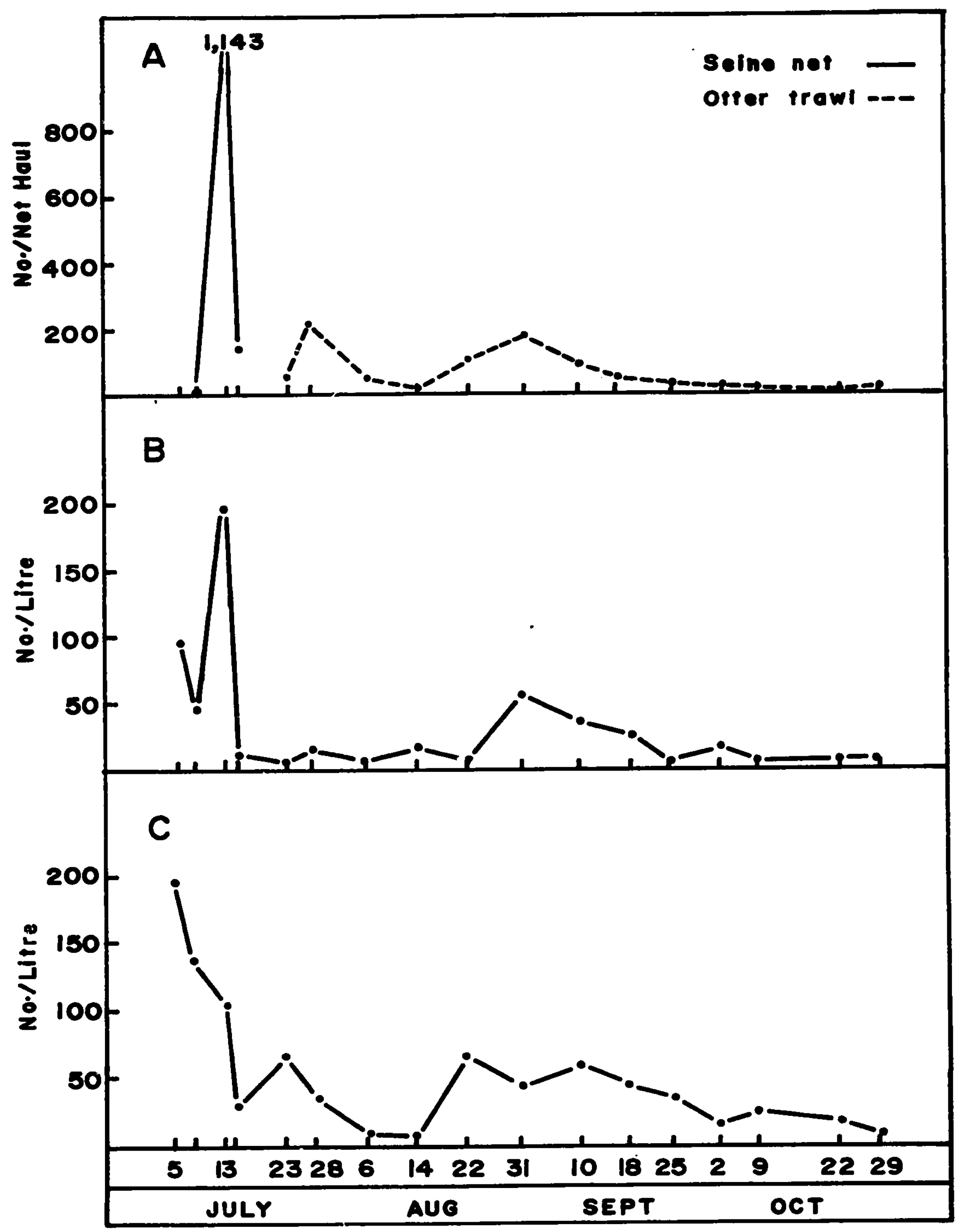
C. Seasonal growth and changes in rate

The estimation of fish fry growth in natural populations is often complicated by the continued recruitment of young from extended adult spawning periods. Workable data allowing estimation of seasonal growth and changes in rate in the present study are based on the continuous sampling of the first major group of young-of-the-year alewives spawned using seine materials in the July 5 - 15 period and trawl samples thereafter. Use of the otter trawl in offshore waters, from July 23, prevented collection of the late hatching young which began to occur in the July 15 seine sample (Tables 4, 11).

The three stage growth curve calculated for these samples is similar to that reported by Lagler and Applegate (1943) for young-of-the-year gizzard shad. Calculations from their Foots Pond data for 212 fish ranging from 19 - 88 mm in standard length, but restricted to 4 samples, showed growth rate to be most rapid in the June 26 - July 10 interval (circa. 1.8 mm/day), intermediate in the July 10 - August 20 period (circa 0.2 mm/day) and minimal during the time between August 20 and November 13 (circa 0.07 mm/day).

The first change in growth rate in this study calculated to occur between July 13 and 15 appeared to be the associated with resource reduction by the large number of individuals present prior to July 15 (Fig. 9). In the July 5 - 13 interval when the growth rate of young Alosa was most rapid, the copepod-cladocera food supply was more than twice as abundant as it was in 13 of the 14 subsequent plankton samples taken. Keast (1965) has noted that the most active growth of young-of-the-year occurs when their major food resource is most abundant. This reduction

Figure 9. Abundance of alewives, cladocerans (B) and copepods (C) in Lake St. Clair.



A
1,143
Seine net
Otter trawl
No./Net Haul
800
600
400
200
B
No./Litre
200
150
100
50
C
No./Litre
200
150
100
50
5
13
23
28
6
14
22
31
10
18
25
2
9
22
29
JULY
AUG
SEPT
OCT

in growth rate is reflected by the decrease in the average number of organisms/stomach from peak values for smaller individuals taken on July 13 to minimum levels for larger Alosa captured on July 23 (Table 12, Fig. 7A,B). Although the diversity of the food supply of the young alewife is greater with increase in fish size, the continual degeneration in fish condition despite wide variations in the average numbers of organisms/stomach is indicative that the total food supply available is not adequate to sustain growth at the rate observed in early July (Fig. 7A, B, C).

The second reduction in growth rate in the early Fall appeared to be related to physical rather than biological parameters. It corresponded with a major decrease of 4.3°C in the temperature of the water column from 23.0° to 18.7° between September 10 and 18. The negligible growth rate of .02 m/day observed in the Fall (Table 3, Fig. 7A) corresponded with an average water column temperature of 16.6°C. Similar data has been presented concerning growth and water temperature for other species by other workers. Andrews and Stickney (1972) indicated that growth of the channel catfish was poor when water temperature decreased below 16°C - 18°C. Shields (1956) reported that the growth of 28 species including the gizzard shad began in the Spring when water temperatures reached 15.6°C.

D. Relative growth

The elimination of time as a variable allows the comparison of growth in terms of any body 'measure' (weight, appendage or dimension such as maximum body depth and width) relative to body length according to Huxley's Power Law for Allometric Growth. (See materials and methods).

For length-weight data, an α or n value of 3.0 indicates growth without change in shape or specific gravity. The calculated α value of 3.22 for young-of-the-year alewives from Lake St. Clair falls within the 2.0 - 3.5 range commonly observed by other authors for this and other species and supports the observation that the length-weight relationship amongst fishes is rarely isometric (Royce 1972). Odell (1934) presented length-weight information for 222 immature alewives in Seneca Lake, New York (α = 2.78) but included neither empirical data nor the equation strictly for young-of-the-year individuals. This is unfortunate as the comparison of length-weight data for Alosa of the same length in the 2 lakes would reflect the relative suitability of the two environments to support these young individuals. The empirical data, calculated equation, corresponding power curve, and empirical data of the length-weight relationship for 134 young-of-the-year alewives from Lake St. Clair are presented to serve as a basis for future comparisons (Tables 13, 14, Fig. 8).

For linear measurements, α values of 1.0 indicate isometric growth of body parts relative to body length. Such values are not common (Graham 1956). Allometric α values smaller than unity show that the body part grows relatively faster than the body while those greater than unity show the opposite relationship. The α values presented above for relative growth of the caudal appendage and body depth and width in relation to standard length suggest two things:

Since the caudal appendage grows relatively faster than the body, larger young-of-the-year alewives have the capability to outswim smaller individuals of the school. This might allow the larger individuals to remain at the head or perimeter of the school as hypothesized in section B of the discussion.

Because growth occurs faster vertically than laterally relative to body length, the body depth at any given size would be of greater importance in determining the vulnerability of the young alewives to predator species. Schwartz (1958) has indicated that body length and depth are of greatest significance in determining the forage value of two related species (gizzard and threadfin shad).

E. Recommendations for future research

The alewife is known to be a major forage species in lakes of New York and New Jersey. This freshwater herring is consumed by smallmouth bass, Micropterus dolomieui (Webster 1954) largemouth bass Micropterus salmoides and yellow perch Perca flavescens (Gross 1953) northern pike Esox lucius (Odell 1934) and lake trout Salvelinus namaycush (Webster Bentley and Galligan 1959).

In the Great Lakes Alosa serves as food for the walleye Stizostedion vitreum (Lake Erie; Price 1963), and the bowfin Amia calva and burbot Lota lota in addition to most of the other species indicated above (Lake Michigan; Wagner 1972).

Many of these predators known to utilize the alewife as a food resource have supported a successful fishery on Lake St. Clair. Except for Lake Erie commercial production in terms of pounds of fish per acre has proven to be higher in Lake St. Clair than in any of the Great Lakes (Rawson 1952). Furthermore, the coho salmon, known to feed heavily on young-of-the-year and yearling alewives in Lake Michigan (Brown 1972), has recently been identified from Lake St. Clair waters.

In view of the preceding information and the apparent success of young alewives in Lake St. Clair, future research directed at the determination of the actual forage value of the species should be of prime importance.

Research concerning the diurnal feeding habits of young alewives and the vertical and horizontal distribution of young individuals in large shallow lakes where standard thermoclines are not evident, both poorly represented in the literature, could be conducted on Lake St. Clair.

Little published information is available concerning temperature preference of alewives in their first winter of life. Lakes St. Clair, Erie and Huron, because of great differences in depth provide a potential study area for the determination of the preferred temperature for young alewives in the natural habitat.

The University of Windsor, because of its proximity to these three lakes and the Detroit and St. Clair Rivers, is in an excellent geographic location for the development of a Great Lakes Fisheries Research Program.

SUMMARY AND CONCLUSIONS

1. In this first report concerning the life history and ecology of the alewife Alosa pseudoharengus (Wilson) in Lake St. Clair the objectives were to provide information on the time and location of spawning and subsequent abundance of the young-of-the-year in this area of the lake, to determine their food habits and selectivity in feeding, seasonal growth and the major biological and physical parameters associated with changes in rate, and to present relative growth data as an aid to future studies of this young river herring in freshwater.

2. Sampling was continued on a weekly basis subject to weather conditions from July 5 to October 29, 1971, at a location near Stoney Point, Ontario. A total of 17 seine hauls and 16 otter trawls were completed. Four 10 litre, and twenty-six 2 litre plankton samples were taken in seine and otter trawl areas respectively. Data from 4 seine hauls (July 5 - 15) and 13 otter trawls (July 23 - October 29) were used in determinations of food habits and food selection, seasonal growth and changes in rate and relative growth.

3. Alewife spawning activity occurred in the vicinity of the sampling area during the first 3 weeks of June. The recurrence of young individuals in the catch from early July to late October demonstrates that the environment of the lake is suitable for the establishment of the early life stages of the species.

4. The diet of Alosa consists primarily of zooplankton. Cladocerans and copepods were always positively selected.

5. Young alewives consumed the largest groups of food

organisms available with time, switching to successively smaller items as each resource approached depletion. Copepods and 3 cladoceran genera, the largest 4 groups of zooplankters removed from alewife stomachs were of greatest importance to the smaller young (10 - 29 mm standard length) 100% of which were collected July 28 or earlier. Bosmina, the smallest preferred food item was of greatest value to the larger alewives (30 - 59 mm standard length) 89.7% of which were taken after July 28. Copepod patterns of locomotion may determine their prime importance in the alewife diet in the presence of larger relatively stationary cladocerans.

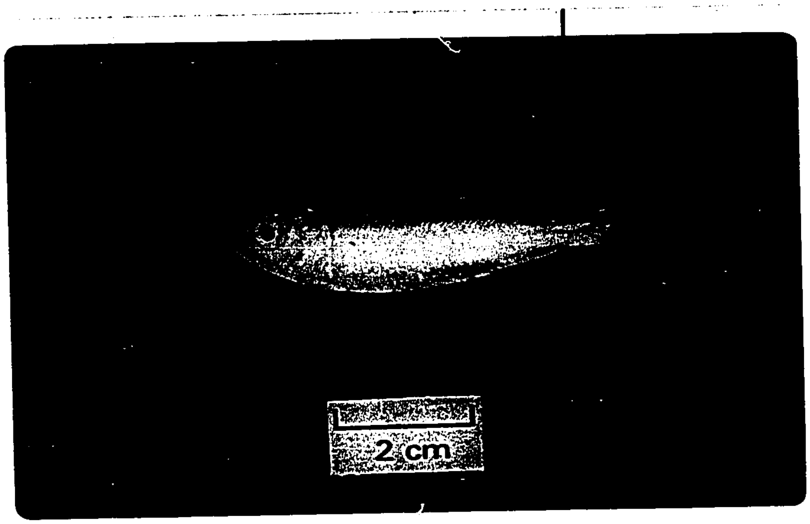
6. Young alewives avoided the small but abundant rotifers in feeding except when the copepod-cladoceran food resource was reduced in their immediate vicinity.

7. The distribution of rotifers and other food organisms in July 28, August 6 and October 2 stomach samples suggests location of the larger alewives at the anterior and/or perimeter of the school and younger individuals at the posterior and/or interior of the school.

8. Young alewives feed on chironomids in the sediment. They are facultative rather than obligate planktivores.

9. Growth rate of young alewives over a 4-month period showed 2 inflections, one in July, the other in September. The first inflection corresponded with a severe decrease in the copepod-cladoceran food supply and the second with a sudden decrease in temperature of the water column and sustained low temperatures thereafter.

10. Increases in weight caudal fin length and maximum body depth and width were allometric and tachyauxetic.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APPENDIX

Appendix I

Table 14. Morphometric and weight data for young-of-the-year alewives in Lake St. Clair (July - October, 1971)

No. fish	Standard length (mm)	Caudal fin length (mm)	Maximum body depth (mm)	Maximum body width (mm)	Weight (gms)
2	16	3.5	2.00	1.50	0.05
0	17	-	-	-	-
2	18	3.5	2.50	1.75	0.05
2	19	4.0	3.00	1.75	0.07
3	20	4.5	3.75	1.75	0.07
0	-	-	-	-	-
2	22	5.0	4.50	2.25	0.11
2	23	5.0	5.00	2.25	0.14
4	24	5.5	5.50	2.75	0.15
2	25	6.0	6.00	2.75	0.20
3	26	5.0	6.00	3.00	0.23
4	27	6.0	6.75	3.00	0.26
3	28	6.5	6.75	3.00	0.28
1	29	6.0	7.00	3.00	0.31
3	30	6.5	7.00	3.25	0.32
2	31	7.0	8.00	3.50	0.41
4	32	7.5	8.25	3.75	0.49
3	33	7.0	8.00	4.00	0.47
3	34	8.5	9.00	4.00	0.56
2	35	8.0	8.75	4.00	0.58
3	36	8.5	9.25	4.50	0.66
1	37	9.0	9.50	4.00	0.67
4	38	9.5	10.00	4.25	0.80
3	39	9.0	10.00	4.75	0.83
4	40	10.0	10.25	4.75	0.92
5	41	10.0	10.50	4.75	0.96
3	42	10.5	11.00	5.00	1.09
4	43	10.0	11.25	5.00	1.09
4	44	10.5	11.00	5.00	1.16
2	45	10.5	11.75	5.25	1.26
4	46	11.0	11.75	5.50	1.26
4	47	11.0	12.25	5.75	1.40
6	48	12.0	12.50	6.00	1.45
4	49	12.0	13.00	6.00	1.55
6	50	12.0	13.50	6.25	1.63
4	51	12.5	13.75	6.25	1.77
6	52	12.5	13.50	6.50	1.81
5	53	12.0	14.00	6.00	1.80
7	54	12.5	14.25	6.25	1.98
3	55	13.5	15.25	7.00	2.27
2	56	14.5	15.50	7.00	2.47
2	57	13.5	15.00	7.00	2.44
1	58	14.0	17.00	8.00	2.65

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